INTERNATIONAL APPLICATION AS ORIGINALLY FILED

DESCRIPTION

POWER SUPPLY UNIT

Technical Field

The present invention relates to a power-supply unit and more particularly to a power-supply unit for the purpose of harmonic current suppression and power-factor improvement.

Background Art

In the equipment receiving the supply of electric power from a commercial alternating current power supply, the power supply is required to suppress the generation of harmonic current. Since a circuit having a harmonic current suppression function simultaneously contains a power-factor improvement function, the circuit is often called a power-factor improvement circuit as in a power-supply unit shown in a related example in Patent Document 1.

Now, in the equipment having a standby mode as in televisions, for example, it is also necessary to operate a waiting circuit (for example, a reception circuit for receiving only a power-supply on signal from a remote control system) during standby. However, it is very inefficient to make the whole power-supply unit operated for a waiting circuit consuming only a very small amount of electric power. In particular, since the reduction of electric power loss on standby is required lately, it is necessary to develop countermeasures for that. Then, in a switching power-supply circuit of a related example in Patent Document 1, a main power-supply circuit which is not operated during standby and a secondary power-supply circuit which is operated to constantly supply a small amount of electric power, during standby also, are contained, and both the main power-supply circuit and the secondary power-supply circuit are connected to an alternating current power supply.

In the switching power-supply circuit of a related example in Patent Document 1, since large harmonic current is generated in the main power-supply circuit having a large electric power supply capacity, even if the circuit structure becomes a little complicated, a harmonic current suppression circuit is contained and, on the contrary, since small harmonic current is generated in the secondary power-supply circuit having a small electric power supply capacity, no harmonic current suppression circuit is contained.

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2003-18842

Disclosure of Invention

Problems to be solved by the Invention

Now, in the equipment such as televisions, there are cases where a power supply having various output voltages is required, and also there is the demand that a secondary power-supply circuit which can be used not only on standby, but also for other purposes during normal operation is needed. Practically, necessary voltages on standby are often the voltages of + 5 V and + 3.3 V required for operation of simple digital circuits, for example, and also the voltages of + 5 V and + 3.3 V can be used for various other purposes. Therefore, a power-supply unit is designed so as to be fitted not for the amount of power consumption on standby, but for the amount of power consumption during normal operation. In this case, the secondary power-supply circuit is designed so as to have much power supply capacity in reserve.

However, in the case of the related example in Patent Document 1, for example, the secondary power-supply circuit contains no harmonic current suppression circuit. Accordingly, when the amount of power supply in the secondary power-supply circuit increase, that means the increase of the amount of generation of harmonic current and then, if

the situation is left as it is, the means is mistaken for the end.

Means for Solving the Problems

In order to solve the above-described problem, it is an object of the present invention to provide a power-supply unit in which a main power-supply circuit having a harmonic current suppression circuit and a secondary power-supply circuit having no harmonic current suppression circuit are contained and, while electric power is supplied from the secondary power-supply circuit, harmonic current is suppressed and simultaneously the power factor can be improved.

In order to attain the above-described object, a power-supply unit of the present invention comprises a main power-supply circuit and a secondary power-supply circuit, both connected to an alternating current power supply; and an input current control circuit contained in the main power-supply circuit. In the power-supply unit, the input current control circuit controls an input current to the main power-supply circuit so that harmonic current may be suppressed in a current of the summation of the input current to the main power-supply circuit and an input current to the secondary power-supply circuit.

A power-supply unit of the present invention comprises a main power-supply circuit and a secondary power-supply circuit, both connected to an alternating current power supply; and an input current control circuit contained in the main power-supply circuit. In the power-supply unit, the input current control circuit controls an input current to the main power-supply circuit so that a current of the summation of the input current to the main power-supply circuit and an input current to the secondary power-supply circuit may be substantially proportional to an input voltage to the input current control circuit.

A power-supply unit of the present invention comprises a main power-supply circuit and a secondary power-supply circuit, both

connected to an alternating current power supply; an input current control circuit contained in the main power-supply circuit; and circuit current detection means contained in the input current control circuit. In the power-supply unit, a current of the summation of an input current to the main power-supply circuit and an input current to the secondary power-supply circuit flows in the circuit current detection means, and the input current control circuit controls the input current to the main power-supply circuit so that harmonic current may be suppressed in the current flowing in the circuit current detection means.

Furthermore, a power-supply unit of the present invention comprises a main power-supply circuit and a secondary power-supply circuit, both connected to an alternating current power supply; an input current control circuit contained in the main power-supply circuit; and circuit current detection means contained in the input current control circuit. In the power-supply unit, a current of the summation of an input current to the main power-supply circuit and an input current to the secondary power-supply circuit flows in the circuit current detection means, and the input current control circuit controls the input current to the main power-supply circuit so that the current flowing in the circuit current detection means may be substantially proportional to an input voltage to the input current control circuit.

Then, a power-supply unit may further comprise a first rectifying circuit connected between the alternating current power supply and the input current control circuit, the first rectifying circuit contained in the main power-supply circuit; a second rectifying circuit connected to the alternating current power supply, the second rectifying circuit contained in the secondary power-supply circuit; and a smoothing circuit connected to the second rectifying circuit, the smoothing circuit contained in the second power-supply circuit.

Moreover, a power-supply unit may further comprise a switch connected between the alternating current power supply and the first rectifying circuit.

A power-supply unit may further comprise a first rectifying circuit connected between the alternating current power supply and the input current control circuit, the first rectifying circuit contained in the main power-supply circuit; a reverse-current prevention diode connected to the output of the first rectifying circuit, the reverse-current prevention diode contained in the secondary power-supply circuit; and a smoothing circuit connected to the output of the reverse-current prevention diode, the smoothing circuit contained in the secondary power-supply circuit.

Furthermore, in a power-supply unit of the present invention, the input current control circuit is a boost converter. Moreover, the boost converter contains an inductance element one terminal of which is connected to one output terminal of the first rectifying circuit, a diode connected between the other terminal of the inductance element and an output terminal of the main power-supply circuit, a switch element connected between the other terminal of the inductance element and the other output terminal of the first rectifying circuit, and a smoothing capacitor connected between an output terminal of the main power-supply circuit and the other output terminal of the first rectifying circuit.

In a power-supply unit of the present invention, the input current control circuit is a flyback converter. Moreover, the flyback converter contains a transformer in which one terminal of a primary winding is connected to one output terminal of the first rectifying circuit, a switch element connected between the other terminal of the primary winding and the other terminal of the first rectifying circuit, a diode connected between one terminal of a secondary winding of the transformer and an output terminal of the main power-supply circuit,

and a smoothing capacitor connected between an output terminal of the main power-supply circuit and the other terminal of the secondary winding.

Advantages

In a power-supply unit of the present invention, in addition to a main power-supply circuit having a circuit generally called a harmonic current suppression circuit or power-factor improvement circuit, a secondary power-supply circuit having no harmonic current suppression circuit or improvement circuit is contained, and moreover, although a load current is taken out from the secondary power-supply unit, an input current to the main power-supply circuit is controlled so that a current of the summation of the input current to the main power-supply circuit and an input current to the secondary power-supply circuit may be substantially proportional to an input voltage to an input current control circuit, and thus, in the power-supply unit as a whole, an input current is made substantially a sine wave and, as a result, the generation of harmonic current is suppressed and simultaneously the power factor can be improved.

Brief Description of the Drawings

Fig. 1 is a circuit diagram of an embodiment of a power-supply unit of the present invention.

Fig. 2 is a characteristic diagram showing a schematic waveform image of a voltage or current of each portion of the power-supply unit in Fig. 1, in which it is assumed that only a main power-supply circuit is contained in the power-supply unit.

Fig. 3 is a characteristic diagram showing a schematic waveform image of a voltage or current of each portion of the power-supply unit in Fig. 1.

Fig. 4 is a circuit diagram of another embodiment of a power-

supply unit of the present invention.

Fig. 5 is a circuit diagram of further another embodiment of a power-supply unit of the present invention.

Fig. 6 is a characteristic diagram showing the relation between an input voltage and an input current in the power-supply unit in Fig. 5.

Fig. 7 is a characteristic diagram showing the relation between an input voltage and an input current in a related power-supply unit.

Fig. 8 is a circuit diagram of another embodiment of a power-supply unit of the present invention.

Fig. 9 is a circuit diagram of another embodiment of a power-supply unit of the present invention.

Fig. 10 is a circuit diagram of another embodiment of a power-supply unit of the present invention.

Reference Numerals

10, 20, 30, 40, 50, and 60 power-supply units

11, 41, and 61 main power-supply circuits

12, 42, and 62 input current control circuits

13 and 63 control circuits

14, 21, and 64 secondary power-supply circuits

AC alternating current power supply

SW switch

D1 full-wave rectifier (first rectifying circuit)

C1 noise rejection capacitor

L1 inductance element

D2 diode

Q1 switch element

R1 and R2 resistors (circuit current detection means)

C2 smoothing capacitor

D3 and D4 diodes (second rectifying circuits or reverse-current prevention diodes)

C3 smoothing capacitor (smoothing circuit)

T1 transformer

N1 primary winding

N2 secondary winding

Best Mode for Carrying Out the Invention

Embodiment 1

Fig. 1 is a circuit diagram of an embodiment of a power-supply unit of the present invention. In Fig. 1, a power-supply unit 10 contains a main power-supply circuit 11 and a secondary power-supply circuit 14. The main power-supply unit 11 is connected to an alternating current power supply AC through a switch SW. The secondary power-supply circuit 14 is directly connected to the alternating current power supply AC, but not through the switch SW.

Moreover, when required, another power-supply circuit such as a DC-DC converter, etc., is connected on the output side of the main power-supply circuit 11 and the secondary power-supply circuit 11 each so as to obtain a desired output voltage, although the description is omitted since it is not the point of the invention. Moreover, what includes the power-supply circuit each may be referred to as a main power-supply circuit and a secondary power-supply circuit.

The switch SW is for turning on and off the main power-supply circuit 11. During standby, a current is supplied only to the secondary power-supply circuit in such a way that the main power-supply circuit 11 is turned off, and then, the power loss on standby can be reduced. Moreover, although it is desirable to contain the switch SW in the present embodiment, the switch SW is not essential and the main power-supply circuit 11 may be directly connected to the alternating current power supply AC.

First, on the assumption that the secondary power-supply circuit 14 is not contained, the structure and operation of the main power-

supply circuit 11 is described. The main power-supply circuit 11 contains a full-wave rectifier D1 as a first rectifying circuit, a noise rejection capacitor C1, and an input current control circuit 12. One input terminal of the full-wave rectifier D1 is connected to one terminal of the alternating current power supply AC through the switch SW and one more input terminal is connected to the other terminal of the alternating current power supply AC. The two output terminals of the full-wave rectifier D1 are connected to the input current control circuit 12. The output of the input current control circuit 12 constitutes the output of the main power-supply circuit 11. Then, the noise rejection capacitor C1 is connected between the two output terminals of the full-wave rectifier D1. The capacitance of the capacitor C1 is sufficiently small in comparison with what is used as a smoothing capacitor in the 60-Hz alternating current power supply and practically does not have a function to smooth variations due to the frequency change of an alternating current power supply.

The input current control circuit 12 is what is generally called a harmonic current control circuit or power-factor improvement circuit and composed of an inductance element L1, a diode D2, a switch element Q1, a resistor R1, a smoothing capacitor C2, and a control circuit 13. The input current control circuit 12 is basically a boost converter (step-up chopper circuit) and then, one terminal of the inductance element L1 is connected to one input terminal of the full-wave rectifier D1 and the other terminal is connected to the anode of the diode D2. The cathode of the diode D2 is connected to one output terminal of the main power-supply circuit 11. The other terminal of the inductance element L1, that is, the connection point to the diode D2 is connected to one terminal of the switch Q1. The other terminal of the switch Q1 is connected to another output terminal of the main power-supply circuit 11 and simultaneously connected to the other output terminal of the full-wave rectifier D1 through the resistor R1.

Then, the smoothing capacitor C2 is connected between the cathode of the diode D2 and the other terminal of the switch Q1.

In the input current control circuit 12, the switch Q1 is controlled by the control circuit 13 to be turned on and off. The control circuit 13 is connected to one terminal (point a) of the inductance element L1 to detect the input voltage. Furthermore, the control circuit 13 is connected to both terminals (point b and point c from the side of the full-wave rectifier D1) of the resistor R1, and then, the electric potential at both terminals of the resistor R1 is detected and the amount of current flowing through the resistor R1 is detected on the basis of the difference between them. Moreover, the control circuit 13 is also connected to the cathode (point d) of the diode D2 to detect the output voltage of the input current control circuit 12. Moreover, such a control circuit 13 is a general control circuit and often seen as IC products for harmonic current control or power-factor improvement like UC1854 of Texas Instrument Incorporated and ML4821 of Fairchild Corporation, for example.

The operation of the power-supply unit 10 where it is assumed that only the main power-supply circuit thus constructed is contained is described with reference to Fig. 2. Fig. 2 shows a schematic waveform image of a voltage or current of each portion of the power-supply unit 10 and they are greatly simplified in comparison with their actual waveforms.

In the main power-supply circuit 11, when the voltage of the alternating current power supply is a sine wave as shown by Vac in Fig. 2, since no smoothing capacitor is connected in the output of the full-wave rectifier D1, a voltage which is full-wave rectified by the full-wave rectifier D1 and shown by Va in Fig. 2 is applied to the input current control circuit 12 substantially as it is. In the input current control circuit 12, switching of the switch element Q1 is performed at a much higher frequency than the frequency of the

alternating current power supply by the control circuit 13. When it is assumed that the frequency of the alternating current is 50 Hz or 60 Hz, the switching frequency of the switch element Q1 becomes about 60 kHz, for example. In this way, a current corresponding to the voltage of one terminal of the inductance element L1 flows into the inductance element L1 each time of switching, and a step-up voltage is output to the cathode of the diode D2 and smoothed. In this case, the input current to the input current control circuit 12 macroscopically becomes a current corresponding to the absolute value of a sine wave which is substantially proportional to the input voltage Va as shown by Ia in Fig. 2. Therefore, the current flowing into the full-wave rectifier D1, that is, the input current of the main power-supply circuit 11 becomes a current of a sine wave which is substantially proportional to the input voltage as shown by Iac in Fig. 2. As a result, the generation of harmonic current is suppressed and at the same time the power factor is improved.

Moreover, microscopically there are small up-and-down variations in the current value corresponding to the switching cycle of the switch element Q1. The up-and-down variations in the current value are more or less smoothed by the noise rejection capacitor C1, but not completely removed.

Here, the operation of the control circuit 13 is described a little more in detail. An oscillation circuit of about 60 kHz is contained in the control circuit 13 and the switch element Q1 is turned on in synchronization with a signal output from the oscillation circuit.

First, it is assumed that the switch element Q1 is in the on state. At this time, a current flows through the inductance element L1 and the switch element Q1 and increases as time passes. The control circuit 13 detects the input voltage of the input current control circuit 12 and a current flowing in the resistor R1. The current

flowing in the resistor R1 in this case is equal to the current flowing in the inductance element L1, and, since the current flowing in the inductance element L1 is the input current to the main power-supply circuit 11, it is understood that the control circuit 13 detects the input current to the main power-supply circuit 11. Accordingly, the resistor R1 becomes a circuit current detection means of the present invention.

Since the current flowing in the resistor R1 is equal to the current flowing in the inductance element L1, while the switch element Q1 is turned on, the current flowing in the resistor R1 increases in the same way as the current flowing in the inductance element L1. When the current flowing in the resistor R1 reaches a value substantially proportional to the input voltage at the time (hereinafter, the current is referred to as a set value), the control circuit 13 turns off the switch element Q1.

Since the set value of current is proportional to the input voltage, the set value of current becomes low when the input voltage is low, for example, and the set value of current also becomes high when the input voltage is high, depending on the phase of the voltage of the alternating current power supply. Furthermore, the set value increases and decreases depending on the output current of the main power-supply circuit 11. That is, when the output current is small (when the main power-supply circuit has a light load), the set value becomes low, and, on the contrary, when the average value of the output current is larger (the main power-supply circuit has a heavy load), the set value becomes high in correspondence with that. The control is performed in such a way that the control circuit 13 detects the output voltage of the input current control circuit 12 and the set value of current is increased and decreased so as to maintain the output voltage at a constant value.

When the switch element Q1 is turned off, the current flowing in

the inductance element L1 decreases and, in accordance with that, the current flowing in the resistor R11 also decreases. Although the current flowing in the inductance element L1 finally becomes zero when the current continues to flow as it is, since the switch element Q1 is made to turn on at a fixed cycle, the switch element Q1 is turned on by the control circuit 13 before the current actually becomes zero. When the switch element Q1 is turned on, the current starts to flow in the inductance element L1 and the resistor R1 once again and the above-described operation is repeated.

Moreover, in the above description, although a continuous current type in which the current flows in the inductance element L1 does not become zero is assumed, a critical current type in which the current flowing in the inductance element L1 once becomes zero and, by triggering that, the switch element is turned on and the current starts to flow once again and a discontinuous current type in which, after the current has become zero, a period where the current is zero continues for a while and then, the switch is turned on and the current starts to flow once again may be considered and then, there is no difference in the practical operation concerning harmonic current control and power-factor improvement. Furthermore, these modes may be switched in accordance with the state of the load in the main power-supply circuit 11.

In this way, when switching of the switching element Q1 is performed by the control circuit 13, the input current to the input current control circuit 12 is substantially proportional to the input voltage. Since the input current to the input current control circuit 12 is a current from the alternating current power supply which is input to the full-wave rectifier D1, the generation of harmonic current is thus suppressed. Furthermore, the power factor is improved.

Next, the power-supply unit 10 in which the secondary power-supply circuit 14 is contained is described. The secondary power-supply

circuit 14 contains a diode D3 as a second rectifying circuit of a half-wave rectification type and a capacitor C3 as a smoothing circuit. The anode of the diode D3 is connected to one terminal of the alternating current power supply AC and the cathode is connected to one output terminal of the secondary power-supply circuit 14. One terminal of the smoothing capacitor C3 is connected to the cathode of the diode D3 and the other terminal is connected to another output terminal of the secondary power-supply circuit 14. Although the other terminal of the capacitor C3 is also connected to the other terminal of the alternating current power supply AC according to a related technology, the other terminal of the capacitor C3 is connected to the other terminal of the switch element Q1 of the main power-supply circuit 11 in the present invention. That is, the other terminal of the capacitor C3 is connected to the other terminal of the alternating current power supply AC through the resistor R1 and the full-wave rectifier D1 of the main power-supply circuit 11.

Moreover, in the secondary power-supply circuit 14, when the above-described connection is performed, not only the diode D3 as a second rectifying circuit, but also a part of the full-wave rectifier D1 of the main power-supply circuit 11 function as a rectifying circuit of the secondary power-supply circuit 14.

The operation of the power-supply unit 10 including the secondary power-supply circuit 14 constructed in this way is described with reference to Fig. 3. In the same way as Fig. 2, Fig. 3 shows a schematic waveform image of a voltage or current of each portion of the power-supply unit 10 and they are greatly simplified in comparison with their actual waveforms. Furthermore, since the voltage waveforms shown by Vac and Va in Fig. 3 are the same as in Fig. 2, their description is omitted.

The secondary power-supply circuit 14 contains the second rectifying circuit of a half-wave rectification type and the smoothing

circuit, and does not contain a circuit corresponding to a harmonic current suppressor circuit. Therefore, the current flowing into the secondary power-supply circuit 14 from the alternating current power supply AC is a half cycle of either in one cycle of an alternating current frequency and is also limited to the period where the amplitude of the alternating current voltage is large, and then, the flowing current becomes pulsed-shaped as shown by Id3 in Fig. 3. The larger the output current of the secondary power-supply circuit 14 is, the higher the height of the pulse is.

However, a current returning to the side of the alternating current power supply AC from the secondary power-supply circuit 14 flows through the resistor R1 of the input current control circuit 12. That is, a current of the summation of the input current flowing to the main power-supply circuit 11 and the input current flowing to the secondary power-supply circuit 14 from the alternating current power supply AC flows in the resistor R1. Then, in the input current control circuit 12, switching of the switch element Q1 is performed so that the current of the summation may become a value which is substantially proportional to the input voltage Va. Accordingly, the summation of the current flowing to the main power-supply circuit 11 from the alternating current power supply AC and the current Id3 flowing to the secondary power-supply circuit 14 becomes substantially proportional to the input voltage Va to the input current control circuit 12 and then, the generation of harmonic current is suppressed and simultaneously the power factor is improved.

Concretely, first, during a period in which there is no current flowing to the secondary power-supply circuit 14 from the alternating current power supply AC, the same waveform as in the case where the secondary power-supply circuit 14 does not exist is obtained. That is, the input current control circuit 12 functions as a harmonic current suppression circuit only for the main power-supply circuit 11.

Then, like a waveform shown by Ia in Fig. 3, as a result, the input current control circuit 12 operates so that the current flowing to the main power-supply circuit 11 from the alternating current power supply AC may decrease only during a period where there is a current flowing to the secondary power-supply circuit 14 from the alternating power current supply AC. In this case, the input current control circuit 12 does not function as a harmonic current suppression circuit only for the main power-supply circuit 11. Then, in this way, the current of the summation of the input current to the main power-supply circuit 11 and the input current to the secondary power-supply circuit 14 becomes a current as an absolute value of a sine wave substantially proportional to the input voltage Va. Accordingly, the current flowing to the power-supply unit 10 from the alternating current power supply AC becomes a current of a sine wave which is substantially proportional to the input voltage as shown by Iac in Fig. 3. As a result, the generation of harmonic current is suppressed and simultaneously the power factor is improved.

Moreover, like a waveform shown by Ia in Fig. 3, when the input current to the main power-supply circuit 11 simply decreases, even if it is temporary, the output current decreases. However, practically, the electric current value (set value) which is proportional to the input voltage constituting the condition making the switch element Q1 turn off in the input current control circuit 12 increases as a whole, the input current to the main power-supply circuit 11 during a period where there is no input current to the secondary power-supply circuit 14 increases, the total current flowing to the main power-supply circuit 11 during one cycle of the alternating current power supply does not change, and accordingly, there is no case where the output current from the main power-supply circuit 11 becomes insufficient.

Embodiment 2

Fig. 4 is a circuit diagram of another embodiment of a power-

supply unit of the present invention. In Fig. 4, the same reference numeral is given the same or equivalent portion as in Fig. 1 and the description is omitted.

In a power-supply unit 20 shown in Fig. 4, a diode D4 is contained between the cathode of the diode D3 and the other terminal of the alternating current power supply AC in such a way that the cathode of the diode D4 is connected to the cathode of the diode D3. A second rectifying circuit of a full-wave rectification type is constructed by the diode D3 and the diode D4, and a secondary power-supply circuit 21 is constituted by the second rectifying circuit and the capacitor C3. Moreover, the power-supply unit 20 is not different from the power-supply unit 10 shown in Fig. 1 except in that the second rectifying circuit contained in the secondary power-supply circuit 21 is of a full-wave rectification type.

In the power-supply unit 20 constituted in this way, a current flows to the second power-supply circuit 21 only when the amplitude of the input voltage is large in both of the two half cycles in one cycle of the frequency of the alternating current power supply. Then, quite in the same way as in the case of the power-supply unit 10, the value of the summation of the current flowing to the main power-supply circuit 11 from the alternating current power supply AC and the current flowing to the secondary power-supply circuit 21 becomes substantially proportional to the input voltage to the input current control circuit 12. Therefore, an input current which is proportional to the voltage of the alternating current power supply AC flows to the power-supply unit 20 as a whole and, as a result, the generation of harmonic current is suppressed and simultaneously the power factor is improved.

Embodiment 3

Fig. 5 is a circuit diagram of another embodiment of a power-supply unit of the present invention. In Fig. 5, the same reference

numeral is given the same or equivalent portion as in Fig. 1 and the description is omitted.

In a power-supply unit 30 shown in Fig. 5, the main power-supply circuit 11 is directly connected to the alternating current power supply AC, not through a switch. Moreover, the anode of the diode D3 in the secondary power-supply circuit 14 is connected to one output terminal of the full-wave rectifier D1. That is, in the secondary power-supply circuit 14, an output is obtained in such a way that a pulsating voltage after full-wave rectification in the full-wave rectifier D1 is made to pass through the diode D3 and then smoothed by the capacitor C3. Although the circuit structure of the secondary power-supply circuit 14 is the same as that in the power-supply unit 10 shown in Fig. 1, the diode D3 does not function as a rectifier, but functions as a reverse-current prevention diode for preventing a current in the reverse direction flowing to the full-wave rectifier D1 due to the voltage charge in the capacitor C3.

In the power-supply unit 30 constituted in this way, although a current flows to the second power-supply circuit 21 only when the amplitude of the input voltage is large in both of the two half cycles in one cycle of the frequency of the alternating current power supply, quite in the same way as in the case of the power-supply units 10 and 20, the current of the summation of the input current flowing to the main power-supply circuit 11 from the alternating current power supply AC and the input current flowing to the secondary power-supply circuit 21 becomes substantially proportional to the input voltage to the input current control circuit 12. Therefore, an input current which is substantially proportional to the voltage of the alternating current power supply AC flows to the power-supply unit 30 as a whole and, as a result, the generation of harmonic current is suppressed and simultaneously the power factor is improved.

In Fig. 6, the relation between an input voltage and an input

current which has been measured in the power-supply unit 30 is shown by dividing that into the case where the main power-supply circuit 11 has a heavy load and the case where the main power-supply circuit 11 has a light load. The main power-supply circuit having a heavy load means that the load current is large and, in a related circuit, it is meant that the ratio of the input current to the secondary power-supply circuit occupying in the whole input current is small and that it is hard to generate harmonic current. On the contrary, the main power-supply circuit having a light load means that the load current is small and it is meant that the ratio of the input current to the secondary power-supply circuit occupying in the whole current and that it is relatively easy to generate harmonic current. Moreover, for comparison, in Fig. 7, also in the case where the other end of the smoothing capacitor C3 in the secondary power-supply circuit 31 is connected to the other output terminal of the full-wave rectifier D1, the relation between an input voltage and an input current is shown by dividing that into the case where the main power-supply circuit has a heavy load and the case where the main power-supply circuit has a light load. The circuit is basically the same as a circuit in which the secondary power-supply circuit is directly connected to the alternating current power supply and the rectifying circuit is of a full-wave rectification type and the circuit is considered to operate in the same way as the related circuit.

First, in the related circuit, when the main power-supply circuit has a heavy load, as shown in Fig. 7 (a), the input current of the switching power-supply circuit becomes a current waveform corresponding to a sine wave of the input voltage. The protruded portion at the top of the current waveform is caused by the input current to the secondary power-supply circuit. Moreover, the switching frequency of the switch element is about 1000 times the frequency of the alternating current power supply and also, since a

component of the frequency is smoothed to some extent by the noise rejection capacitor, small up-and-down vibrations in the current waveform are suppressed and the vibrations can hardly seen in the illustrated waveform.

Then, when the load of the main power-supply circuit becomes light and the input current of the secondary power-supply circuit relatively increases, as shown in Fig. 7 (b), the input current of the main power-supply circuit decreases and, as a result, the protruded portions at the top of the current waveform caused by the input current of the secondary power-supply circuit are emphasized. In this case, in comparison with the case where the main power-supply circuit has a heavy load, it is understood that harmonic current increases and the power factor is worsened.

On the other hand, in the case of the power-supply unit 30, when the main power-supply circuit has a heavy load, as shown in Fig. 6 (a), the input current of the switching power-supply circuit becomes a current waveform corresponding to the sine wave of the input voltage. Although the protruded portions at the top of the current waveform is caused by the input current of the secondary power-supply circuit, as is understood by comparison with Fig. 6 (a), the protruded portions at the top of the current waveform caused by the input current of the secondary power-supply circuit is small. That is, even if the main power-supply circuit has a heavy load, it is understood that harmonic current is suppressed and the power factor is improved.

Then, when the load of the main power-supply circuit becomes light and the input current of the secondary power-supply circuit relatively increases, as shown in Fig. 6 (b), the input current of the main power-supply circuit decreases and, as a result, the protruded portions at the top of the current waveform caused by the input current of the secondary power-supply circuit are emphasized. However, as is understood by comparison with Fig. 7 (b), the protrusion at the

top of the current waveform is small. That is, even if the load of the main power-supply circuit is light, it is understood that harmonic current is suppressed and the power factor is improved.

In this way, in the power-supply unit 30, it is understood that, in comparison with the related circuit, the generation of harmonic current is suppressed and the power factor is improved.

Moreover, in the power-supply unit 20 shown in Fig. 4, since the point that the second rectifying circuit of the secondary power-supply circuit is a full-wave rectification type is the same as in the power-supply unit 30, although the illustration is omitted, the same result can be obtained in actual embodiments.

On the other hand, in the power-supply unit 10 shown in Fig. 1, the second rectifying circuit of the second power-supply circuit is of a half-wave rectification type. An input current of the secondary power-supply circuit is generated every half cycle of the alternating current power supply, which is different from the power-supply unit 30. Therefore, although this illustration is also omitted, the half cycle of the alternating current has the same waveform as that in the power-supply unit 30 and, since the secondary power-supply circuit practically does not exist during the remaining half cycle, the current waveform becomes a sine wave which is substantially proportional to the voltage waveform.

Embodiment 4

Fig. 8 is a circuit diagram of another embodiment of a power-supply unit of the present invention. In Fig. 8, the same reference numeral is given the same or equivalent portion as in Fig. 1 and the description is omitted.

In a power-supply unit 40 shown in Fig. 8, a transformer T1 is contained instead of the inductive element L1 in the power-supply unit 10 and the primary winding N1 is disposed at the position where the inductance element L1 was placed in the power-supply unit 10. Then,

the diode D2 and the smoothing capacitor C2 in the power-supply unit 10 are connected to the secondary winding N2 of the transformer T1 to form a rectifying-smoothing circuit on the secondary winding side. Also in this case, an input current control circuit 42 is constituted by the transformer T1, the switch element Q1, the resistor R1, the diode D2, the smoothing capacitor C2, and the control circuit 13. In the input current control circuit 42, basically an energy is stored in the transformer T1 when a current flows in the primary winding N1 and, when no current flows in the primary winding, a current flows in the secondary winding and the stored energy is taken out, which constitutes a flyback converter. Then, when the full-wave rectifier D1 as a first rectifying circuit and the noise rejection capacitor C1 are added to that, the main power-supply circuit 41 is constituted.

Moreover, the control circuit 13 is also connected to point d, which is the cathode of the diode D2, to detect the output voltage. However, since both are positioned on the primary winding and secondary winding sides of the transformer T1, electrical insulation is required somehow to connect them.

Except for that, the power-supply unit 40 is the same as the power-supply unit 10. Also in the structure of the secondary power-supply circuit 14, the other terminal of the capacitor C3 is connected to the other terminal of the alternating current power supply AC through the resistor R1 and the full-wave rectifier D1 of the main power-supply unit 41 in such a way that the other terminal of the capacitor C3 is connected to the other terminal of the switch element Q1.

The power-supply unit 40 constructed in this way is the same as the power-supply unit 10, except for that the input current control circuit 42 is constituted as a flyback converter. That is, if there is no secondary power-supply unit 14, the input current control circuit 42 functions as a harmonic current suppression circuit of the

main power-supply circuit 41 and the input current from the alternating current power supply is made substantially a sine wave to suppress the generation of harmonic current. Furthermore, when there is the secondary power-supply circuit 14 and a current flows to the secondary power-supply circuit 14, the input current to the main power-supply circuit 41 is controlled so that the summation of the current flowing to the main power-supply circuit 41 and the current flowing to the secondary power-supply circuit 14 from the alternating current power supply may be substantially a sine wave. As a result, the generation of harmonic current is suppressed and simultaneously the power factor is improved.

Embodiment 5

Fig. 9 is a circuit diagram of another embodiment of a power-supply unit of the present invention. In Fig. 9, the same reference numeral is given the same or equivalent portion as in Fig. 1 and the description is omitted.

In a power-supply unit 50 shown in Fig. 9, the main power-supply circuit 41 is directly connected to the alternating current power supply AC, not through a switch. Moreover, the anode of the diode D3 in the secondary power-supply circuit14 is connected to one output terminal of the full-wave rectifier D1. That is, the secondary power-supply circuit 14 is constituted so that a voltage of the alternating current power supply which has been full-wave rectified by the full-wave rectifier D1 may be rectified by the second rectifying circuit made up of the diode D3 and smoothed by the capacitor C3.

Also in the power-supply unit 50 constructed in this way, although a current flows to the secondary power-supply circuit 14 only when the amplitude of the input voltage is large in both of the two half cycles of one cycle of the frequency of the alternating current power supply, a current of the summation of the current flowing to the main power-supply circuit 41 from the alternating current power supply AC and the

current flowing to the secondary power-supply circuit 14 becomes substantially proportional to the input voltage to the input current control circuit 42 quite in the same way as in the case of the power-supply unit 40. Accordingly, a current substantially proportional to the voltage of the alternating current power supply AC flows to the power-supply unit 50 and, as a result, the generation of harmonic current is suppressed and simultaneously the power factor is improved.

Embodiment 6

Fig. 10 is a circuit diagram of another embodiment of a power-supply unit of the present invention. In Fig. 10, the same reference numeral is given the same or equivalent portion as in Fig. 1 and the description is omitted.

In a power-supply unit 60 shown in Fig. 10, a control circuit 63 instead of the control circuit 13 in the power-supply unit 10 is contained in an input current control circuit 62 in a main power-supply circuit 61. In the control circuit 63, two input terminals are added in addition to the structure of the control circuit 13. Except for this point, the main power-supply circuit 61 is the same as the main power-supply circuit 11 of the power-supply unit 10.

Furthermore, in the power-supply unit 60, the secondary power-supply circuit 64 is directly connected to the alternating current power supply AC. Then, the secondary power-supply circuit 64 contains a resistor R2 in addition to a second rectifying circuit made up of the diode D3 and the smoothing capacitor C3. The resistor R2 is contained between the other terminal of the capacitor C3 and the other terminal of the alternating current power supply AC. Therefore, the same current as a current flowing through the diode D3, that is, the input current to the secondary power-supply circuit 64 flows through the resistor R2 and a voltage corresponding to the flowing current is obtained between both terminals (point e and point f). Then, the voltage between both terminals is connected to the two input terminals

which have been added in the control circuit 63.

As is described above, the voltage between both terminals of the resistor R2 is input to the control circuit 63. Therefore, the control circuit 63 can detect the amount of an input current to the secondary power-supply circuit 64 from the alternating current power supply AC. Then, the control circuit 63 detects not only the current flowing through the resistor R21, but also the current flowing through the resistor R2 and it is made to control switching of the switch element Q1 on the basis of the summation of both. Therefore, as a result, the same controlling is performed as in the control circuit 13 in the power-supply unit 10.

In this way, in the present invention, an object of the suppression of harmonic current and the improvement of power factor can be attained by detecting a current flowing to the secondary power-supply circuit somehow and by controlling a current of the main power-supply circuit on the basis of the added value of the current flowing to the secondary power-supply circuit and the current flowing to the main power-supply circuit.

Moreover, in each of the above-described embodiments, although a resistor is used as a circuit current detection means, another means such as a current coil, for example, may be used.